REMARKS

Claims 1-16 were pending. Claims 1, 7, and 13 have been amended. New claims 17-25 have been added. Reconsideration of the present application is respectfully requested.

At the outset, the Examiner is thanked for the thorough review and consideration of the present application. The Examiner's Final Rejection dated January 13, 2004 has been received and the contents carefully noted.

The Examiner objected to Figure 4 based on the amendment added to the specification on page 6, line 17. Applicants have deleted reference to Fig. 4 on page 6, line 17, and therefore request withdrawal of the objection to the drawings.

In the Office Action, the Examiner required a substitute specification to incorporate the numerous amendments made to the specification. In response, a substitute specification including all of the amendments listed in the previous amendment is provided with this amendment.

The Examiner also objected to some of the amendments to the specification in the previous Amendment. Regarding the amendment on page 8, paragraph beginning on line 15, the reference to "teeth 34" has been amended by changing the numeral "34" to --35--. On page 10, paragraph beginning on line 21, the amendment included changing "substrates 12" to --substrate 12--. Applicants have deleted the entire word rather than one letter to make the amendment readable. In addition, the word --also-- has been added on page 10, line 16, and the sentence that was redundant with the first sentence of the subsequent paragraph and that was inadvertently added has been deleted. Further, on

page 16, paragraph beginning on line 20, the second reference to "electrode 50" has been changed to --electrode 40-- as suggested by the Examiner.

Applicants respectfully request that the Examiner enter the changes made in the attached substitute specification and withdraw the objection to the disclosure. No new matter has been added.

The Examiner rejected claims 1-4, 6, 13, 14, and 16 under 35 USC 103(a) as being unpatentable over Kobayashi (US Patent No. 5,969,225) in view of Itou et al. (US Patent No. 6,119,518). This rejection is respectfully traversed.

Claim 1, as amended, is allowable at least for the reason that claim 1 recites a combination of features including, for example, a semiconductor substrate including a fixed portion, a movable portion, and connecting members for elastically connecting said movable portion to said fixed portion on a plane, said semiconductor substrate having grooves between said fixed portion and said movable portion except at said connecting members.

Claim 13, is amended, is allowable at least for the reason that claim 13 recites a combination of features including, for example, a semiconductor substrate including, on a plane, a fixed portion and a movable portion, said fixed portion having elastically supporting means for supporting said movable portion to allow movement in a predetermined direction with respect to said fixed portion, said movable portion being electrically connected to a predetermined potential.

These novel features of the present invention are discussed in the specification for example on page 7, paragraph beginning on line 20 with reference to Figures 4 and 5. Specifically, a movable portion 30 is formed to have a substantially rectangular plate

shape above the opening 14 by forming grooves surrounding it in the second silicon substrate except at elastically connecting portions, i.e., driving beams 33 and detection beams 34. That is, the movable portion 30 is formed inside the frame 20.

Kobayashi discloses an angular-velocity detection apparatus. The prior art discussed in reference to Figure 8 in Kobayashi includes a fixed substrate 2 formed in a rectangular shape and formed of, for example, a high-resistance silicon material. See column 1, lines 42-47. The movable section 3 is formed of four support sections, 4, 4,... provided on the substrate 2 so as to be positioned at the four corners of the substrate 2, four support beams 5, 5,... which are formed bent in the shape of the letter L in such a manner as to have a portion parallel to the X axis and a portion parallel to the Y axis from each support section 4 toward the central portion, and a rectangular vibrating body 6 which is supported by each support beam 5 in such a manner as to be capable of being displaced in the X-axis and Y-axis directions and that is supported in a spaced apart manner from the surface of the substrate 2.

On page 3 of the Office Action, the Examiner refers to Figure 8 and column 4, lines 11+ of the Kobayashi reference as recognizing the problem of parasitic capacitance causing leakage of drive signals into the detecting means. The Examiner states that Kobayashi lacks a shielding means and cites Itou et al. in an attempt to cure the deficiencies of Kobayashi.

The Examiner states that electrostatic shielding is a well-known solution to the problem of capacitive coupling. The Examiner cites Lemkin et al. on page 4 of the Office Action as an example of pads and wires connected to a substrate to provide shielding.

Itou et al. teaches an angular velocity sensor comprising a semiconductor oscillator, an oscillation exciting unit formed in the surface of the semiconductor oscillator, and an oscillation detecting unit. At least one of electrode wiring lines to be connected with the oscillation exciting unit and electrode wiring lines to be connected with the oscillation detecting unit is covered on its surface with a shield film. *See* column 3, lines 50 to 62.

However, all of the cited references fail to disclose the features recited in claims 1 and 13, namely, a substrate including a fixed portion, a movable portion, and connecting members on the same plane to achieve the novel and non-obvious features of the present invention. The connecting members connect the movable portion to the fixed portion. Grooves are formed to surround the substrate except at the connecting members.

Rather, in Kobayashi, a fixed portion 4 is connected to a movable portion 3 by L-shaped connecting members (support beams) 5, which have portions parallel to two different axes. A rectangular vibrating body 6 is supported by the support beams 5 so as to be displaceable in the X-axis and Y-axis directions and so as to be spaced apart from the surface of the substrate 2. Therefore, the support beams 5 are not on the same plane as the fixed portion 4 and the movable portion 3. Further, Kobayashi does not anywhere discuss forming grooves to surround the substrate 2 except at the support beams 5.

In contrast, in the present invention, the detection beams 34 have a thin bar shape to provide a degree of freedom in movement of the movable portion 30 only in the y direction with elastic deformation of the detection beams 34.

Further, Itou et al. and Lemkin et al. fail to cure the deficiencies of Kobayashi since they are merely cited allegedly for their teachings of shielding. Furthermore,

Applicants respectfully submit that these two prior art references are non-analogous since the references are not in the field of applicant's endeavor or reasonably pertinent to the particular problem with which the inventor was concerned. *In re Oetiker*, 977 F.2d 1443, 1446, 24 USPQ2d 1443, 1445 (Fed. Cir. 1992). Thus, none of the cited references singly or in combination teaches or suggests the features of the present invention.

It can thus be understood that the combination of references do not in any way make obvious the essential features of the present invention as set out in independent claims 1 and 13.

Moreover, as claims 2-4, 6, 14, and 16 each depend from one of independent claims 1 and 13, each of these claims is also allowable for the same reasons as their respective base claim.

As the cited references fail to make obvious the present invention as recited in claims 1-4, 6, 13, 14, and 16, Applicants respectfully request that the rejection of claims 1-4, 6, 13, 14, and 16 under 35 USC 103(a) be withdrawn.

The Examiner rejected claims 5, 7-12, and 15 under 35 USC 103(a) as being unpatentable over Kobayashi in view of Itou et al. as applied to claims 1-4, 6, and 13 above, and further in view of Ward (US Patent No. 6,445,195). This rejection is respectfully traversed.

Claim 7, as amended, is allowable at least for the reason that claim 7 recites a combination of features including, for example, a semiconductor substrate including a fixed portion, a movable portion, and connecting members for elastically connecting said movable portion to said fixed portion on a plane, said semiconductor substrate having

grooves between said fixed portion and said movable portion except said connecting members.

On page 5 of the Office Action, the Examiner states that the combination of Kobayashi in view of Itou et al. does not specifically teach monitor and dummy electrodes. The Examiner cites Ward in an attempt to cure the deficiencies of the other two references.

Ward teaches a drive feed through nulling system including a feed through nulling compensator 36 used in conjunction with a feedback gain control loop 38. As with Itou et al. and Lemkin et al., Applicants respectfully submit that Ward is non-analogous prior art.

Claim 7 has been amended similarly to claims 1 and 13 described above. As discussed above, the combination of Kobayashi and Itou et al. fails to teach a substrate including a fixed portion, a movable portion, and connecting members on the same plane. The connecting members connect the movable portion to the fixed portion. Grooves are formed to surround the substrate except the connecting members.

Ward fails to cure the deficiencies of the other references because there is no description of a substrate having a fixed portion, a movable portion, and connecting members as recited in claim 7 to achieve the novel and non-obvious features of the present invention.

It can thus be understood that the combination of references do not in any way make obvious the essential features of the present invention as set out in independent claims 1 and 7.

Moreover, as claims 5, 8-12, and 15 depend from one of independent claims 1 and 7, each of these claims are also allowable for the same reasons as their respective base claims.

As the combination of references fails to make obvious the present invention as recited in claim 5, 7-12, and 15, Applicants respectfully request that the rejection of claims 5, 7-12, and 15 under 35 USC 103(a) be withdrawn.

Newly added independent claim 17 is similar to independent claims 1, 7, and 13 and recites that the fixed portion is coplanar with the movable portion across the grooves and the connecting members throughout the grooves and the connecting members. This feature is supported at page 7, lines 19 to 26 as mentioned above. Newly added dependent claims 18 and 19 further limit claim 17 by reciting features regarding the connecting members including driving beams. These features are supported at page 8, lines 1 to 13.

Newly added independent claims 20 and 23 and dependent claims 21, 22, 24, and 25 are similarly supported by the specification and drawings. Applicants respectfully submit that new claims 17-25 are allowable over the cited references.

In view of the above remarks, the present application is believed to be in condition for allowance. A prompt notice to that effect is respectfully requested. A petition for a two-month extension of time and the requisite fee are included with this amendment. Although no additional fees are believed to be due, permission is hereby given to charge any unforeseen fees to deposit account 50-1147.

Respectfully submitted,

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~~TITLE OF THE INVENTION~~

A SEMICONDUCTOR DEVICE WITH SHIELDING

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a semiconductor device with shielding.

2. Description of the Prior Art

A semiconductor device with shielding is known. U.S. patent ~~Serial No.~~ <u>no.</u> 6,119,518 discloses an angular velocity sensor having a driving circuit and a detection circuit, wherein a feedback element and lines for detection elements are shielded from lines for drive elements.

SUMMARY OF THE INVENTION

The aim of the present invention is to provide a superior semiconductor device with shielding.

According to the present invention, a first aspect of the present invention provides a first semiconductor device comprising: a circuit substrate and a semiconductor substrate fixed with respect to the circuit substrate; said semiconductor substrate including a ~~fix~~ <u>fixed</u> portion and a movable portion, said movable portion being movable in a predetermined direction with respect to said ~~fix~~ <u>fixed</u> portion, said ~~fix~~ <u>fixed</u> portion <u>being electrically insulated and</u> including ~~with electrical insulation~~: an input electrode for inputting a periodical signal from said circuit substrate to said movable portion to vibrate said movable portion; and an output electrode for outputting a signal indicative of capacitive variation based on

vibration of said movable portion in said predetermined direction toward said circuit substrate; an input wire for connecting said input electrode to said circuit substrate; an output wire for connecting said output electrode to said circuit substrate; and a shield wire connected to a constant potential at said circuit substrate to provide capacitive shielding between said input wire and said output wire.

According to the present invention, a second aspect of the present invention provides a semiconductor device based on the first aspect, wherein a top surface of said semiconductor substrate has a rectangular shape, and said input electrode and said output electrode are arranged at locations corresponding to different sides of said rectangular shape, respectively.

According to the present invention, a third aspect of the present invention provides a semiconductor device based on the first aspect, wherein said shield wire is grounded at said circuit substrate.

According to the present invention, a fourth aspect of the present invention provides a semiconductor device based on the first aspect, wherein said shield wire is arranged near either of said input electrode or said output electrode.

According to the present invention, a fifth aspect of the present invention provides a semiconductor device based on the first aspect, wherein said ~~fix~~ fixed portion further includes ~~with~~ electrical insulation, a dummy electrode capacitively coupled to said input electrode near said output electrode for generating a dummy signal and said semiconductor device further comprises a dummy signal wire connected to said dummy electrode and said circuit substrate,

said dummy signal including a component of said periodical signal induced and being supplied to said circuit substrate ~~to be used~~ to cancel another component of said periodical signal induced in said signal.

According to the present invention, a sixth aspect of the present invention provides a semiconductor device based on the first aspect, wherein said movable portion is movable in another predetermined direction with respect to said ~~fix~~ fixed portion, said semiconductor device further comprising angular velocity detection means for detecting vibration of said movable portion in said another direction to determine an angular velocity around an axis perpendicular to said predetermined direction and another predetermined direction to generate said detection signal.

According to the present invention, a seventh aspect of the present invention provides a semiconductor device comprising: a circuit substrate and a semiconductor substrate fixed with respect to the circuit substrate; said semiconductor substrate including a ~~fix~~ fixed portion and a movable portion, said movable portion being movable in a predetermined direction with respect to said ~~fix~~ fixed portion, said ~~fix~~ fixed portion being electrically insulated and including ~~with electrical insulation~~: an input electrode for inputting a periodical signal from said circuit substrate to said movable portion to vibrate said movable portion; an output electrode for outputting a signal indicative of capacitive variation based on vibration of said movable portion in said predetermined direction toward said circuit substrate; ~~and~~ a monitor electrode for monitoring

capacitive variation based on vibration of said movable portion in said first predetermined direction and supplying a monitor signal to said circuit substrate; an input wire for connecting said input electrode to said circuit substrate; an output wire for connecting said output electrode to said circuit substrate; and a monitor wire for connecting said monitor electrode to said circuit substrate; and a shield wire connected to a constant potential at said circuit substrate to provide capacitive shielding between said input wire and said output wire and between said input wire and said monitor wire.

According to the present invention, an eighth aspect of the present invention provides a semiconductor device based on the seventh aspect, wherein said semiconductor plate is a rectangular plate, and said input electrode and said output electrode are arranged at locations corresponding to different sides of said rectangular plate, respectively.

According to the present invention, a ninth aspect of the present invention provides a semiconductor device based on the seventh aspect, wherein said shield wire is grounded at said circuit substrate.

According to the present invention, a tenth aspect of the present invention provides a semiconductor device based on the seventh aspect, wherein said shield wire is arranged near either of said input wire or said output wire.

According to the present invention, an eleventh aspect of the present invention provides a semiconductor device based on the

seventh aspect, wherein said shield wire is arranged near either of said input wire or said monitor wire.

According to the present invention, a twelfth aspect of the present invention provides a semiconductor device based on the seventh aspect, wherein said ~~fix~~ fixed portion further includes ~~with~~ electrical insulation, a dummy electrode capacitively coupled to said input electrode near said output electrode for generating a dummy signal, and ~~wherein~~ said semiconductor device further comprises a dummy signal wire connected to said dummy electrode and said circuit substrate, said dummy signal including ~~an induced~~ a component of said periodical signal induced and being supplied to said circuit substrate ~~to be used~~ to cancel another component of said periodical signal induced in said signal.

According to the present invention, a thirteenth aspect of the present invention provides a semiconductor device comprising: a circuit substrate and a semiconductor substrate fixed with respect to the circuit substrate; said semiconductor substrate including a ~~fix~~ fixed portion and a movable portion, said ~~fix~~ fixed portion being fixed with respect to said circuit substrate and having supporting means for supporting said movable portion with movement in a predetermined direction with respect to said ~~fix~~ fixed portion, said movable portion being electrically connected to a predetermined potential; capacitive driving means for driving said movable portion, said capacitive driving means including a drive electrode included in said ~~fix~~ fixed portion for inputting a drive signal from said circuit substrate to said movable portion to vibrate said movable portion;

detection means for detecting capacitive variation based on vibration of said movable portion caused by supplying said drive signal to said movable portion, said detection means including a detection electrode included in said ~~fix~~ fixed portion to supply a detection signal to said circuit substrate; and a shield wire pad arranged between said drive electrode and said signal electrode which is neighbor to said one of said drive electrodes; a drive signal wire for connecting said drive electrode to said circuit substrate; a detection wire for connecting said signal electrode to said circuit substrate; and a shield wire connected to said shield wire pad and a constant potential at said circuit substrate to provide capacitive shielding between said drive wires and said detection wire.

BRIEF DESCRIPTION OF THE DRAWINGS

The object and features of the present invention will become more readily apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

Fig. 1 is a plan view of a semiconductor device according to an embodiment of the invention;

Fig. 2 is a sectional side elevation view of the semiconductor device taken on line A-A in Fig. 1;

Fig. 3 is an illustration of a coupling relation in the circuit show in Fig. 1;

Fig. 4 is a plan view of the proto-type of the semiconductor device according to ~~this~~ the present invention.

Fig. 5 is a schematic circuit diagram of a partial signal circuit for the angular velocity sensor according to the ~~embodiment~~ semiconductor device of the present invention.

The same or corresponding elements or parts are designated with like references throughout the drawings.

DETAILED DESCRIPTION OF THE INVENTION

Prior to describing an embodiment of semiconductor device, a proto-type of semiconductor device developed by the inventors will be described.

Fig. 4 is a plan view of the proto-type of semiconductor device according to this invention.

In Fig. 4, the proto-type of semiconductor device is formed with an SOI (silicon on insulator) substrate in which first and second silicon substrates are adhered with adhesive to each other through an oxide film by providing grooves, pads, and wires through well-known semiconductor processes.

The first silicon substrate 11 and the oxide film 13 are partially removed to have an opening 14 at the middle of the first silicon substrate 11 without removal of the second silicon substrate 12. Moreover, the first silicon substrate 11 is fixed to a circuit substrate K1 having a ~~signal~~ processing circuit.

The second silicon substrate 12 is processed to have grooves therein by micro-machining process or the like to provide following parts:

A movable portion 30 is formed to have a substantially rectangular plate shape above the opening 14 by forming grooves surrounding it ~~expect~~ except elastically connecting portions, i.e., driving beams 33 and detection beams 34. That is, the movable portion 30 is formed inside the frame 20.

The driving beams 33 have a U-shape to have degree of freedom in movement of the movable portion 30 only in the x direction with elastic deformation of the driving beams 33.

The detection beams 34 have a thin bar shape to provide a degree of freedom in movement of the movable portion 30 only in the y direction with elastic deformation of the detection beams 34. Thus, the frame 20 of the second substrate 12 supports the movable portion 30 with the driving beams 33 and detection beams 34 with movement of the movable portion 30 in predetermined ~~directions~~ x and y directions and is supported by the first substrate 11 on the circuit substrate K1.

At places where the edges (sides) of the movable portion 30 and the frame 20 ~~facing with~~ face each other, teeth electrodes are formed as follows:

On edges of the opening 14 extending a longitudinal direction of the movable portion 30, drive (input) electrodes 40 having teeth are formed to supply driving signals to provide vibration of the movable portion 30 in the x direction. A portion thereof is formed on ~~the~~ an oxide film ~~14~~ such as the oxide film 13 shown in Figs. 2 and 3, and the teeth 35 facing ~~with~~ the teeth ~~34~~ of drive electrodes 40 are formed at the edge of the movable portion 30 such that the teeth of the drive electrodes 40 interlace with the teeth ~~34~~ 35.

At edges extending in a width (x) direction of the movable portion 30, detection electrodes 50 having teeth are formed. A portion of the detection electrode 50 is formed on the oxide film, and the teeth 36 facing with the teeth of the detection electrodes 50 are formed at the confronting edge of the movable portion 30 such that the teeth of the detection electrodes 50 interlace with the teeth 36. The detection electrode 50 generates a detection (output) signal based on capacitive variation in response to vibration in the y

direction generated from vibration in <u>the</u> x direction when an angular velocity Ω around <u>the</u> z axis is applied to the movable portion 30 during vibration in <u>the</u> x direction.

At corners of the movable portion 30, monitor electrodes 60 having teeth are formed. A portion of the monitor electrode 60 is formed on the oxide film, and the teeth 37 facing with the teeth of the monitor electrode 60 are formed at the edge of the movable portion 30 such that the teeth of the monitor electrode 60 interlace with the teeth 37. The monitor electrode 60 generates a monitor signal indicative of capacitive variation due to vibration of the movable portion 30 in <u>the</u> x direction.

The electrodes 40, 50, and 60 are electrically connected to the circuit substrate with wires 42, 52, and 62.

When a drive signal (periodic signal) including an ac component such as a sine wave signal is applied between the drive electrodes 40, the movable portion 30 vibrates in <u>the</u> x direction with driving beams 33. The monitor electrode 60 generates the monitor signal indicative of variation in capacitance between the teeth of the monitor electrodes 60 and the teeth 37. The monitor signals are used to detect amplitude and frequency of the vibration of the movable portion 30 to control the drive signal.

During vibration of the movable portion 30, if an angular velocity Ω around <u>the</u> z axis is applied to the movable portion 30, a Coriolis force is developed in <u>the</u> y direction at the movable portion 30, so that vibration in <u>the</u> y direction is generated. This varies capacitance between the teeth of detection electrodes 50 and the

teeth 36. The detection signal is used to detect the angular velocity Ω applied to the movable portion 30.

In this semiconductor device, though the detection signal is provided with a relatively small space, stray capacitances generated between wires 42, 52, and 62 affect the detection signal. That is, in Fig. 4, a stray capacitance Cw1 between wires 42 and 62, and a stray capacitance Cw2 between wires 42 and 52 are developed. That is, the wires 52 for the detection signal and wires 62 for the monitor signals are coupled to the wires 42 for the drive signals. Then, the drive signal component is superimposed (induced) on the monitor signal and the detection signal. The magnitude of the drive signal is very strong, so that this considerably affects the accuracy of the detection signal and the monitor signal.

~~The inventor improved this structure.~~ Fig. 1 is a plan view of the semiconductor device according to an embodiment of this invention, and Fig. 2 is also a sectional side elevation view taken on line A-A in Fig. 1.

The semiconductor device shown in Fig. 1 has substantially the same structure as one shown in Fig. 4. That is, the first substrate 11 is supported by the circuit substrate K1. The first substrate 11 has the opening 14. The second ~~substrates~~ substrate 12 and the electrodes are supported by the first substrate 11 through the oxide film 13. The movable portion is supported above the opening 14 by the drive beams 33. Forming grooves in the second substrate 12 with electrical insulation provides the drive electrodes 40, the detection electrodes, the monitor electrodes 60, the driving beams 33,

the detection beams 34, and movable space around the movable portion 30.

The difference is that shield wires 70 and shield pads 71, and dummy electrodes 80 and dummy signal wires 82 are further provided. Moreover, plates 90 on the oxide film 13 support the driving beams 33 with insulation from the frame 20. On this plate 90, a pad 91 is formed and is connected to a potential V1 through a wire 92. This potential may be used ~~for~~ to charge the capacitance for detection electrodes 50 and monitor electrodes 60. However, this plate may be grounded. In this case another circuit for charging the capacitances for the detection electrodes 50 and the monitor ~~electrode~~ electrodes 60 is necessary.

On the drive electrodes 40, the detection electrodes 50, the monitor electrodes 60, and the dummy electrodes 80, pads 51, 61, 81 are formed with aluminum, respectively. Wires 42, 52, 62, 70, and 82 made of gold or the like are bonded to respective pads and respective pads (not shown) at corresponding places on the circuit substrate K1.

Here, the positions of respective electrodes are provided in consideration of capacitive coupling separation. That is, the drive electrodes 40 and the detection electrodes 50 (the monitor electrodes 60) are arranged at different sides of the inner edges of the frame 20 which are perpendicular to each other as ~~show~~ shown in Fig 1.

The shield wires 70 connected to the shield pads 71 are grounded on the circuit substrate K1, that is, the shield ~~electrode~~ pad 71 and the shield wire 70 are maintained at a constant potential to

reduce capacitive coupling. The shield pad 71 is arranged between the drive electrode 40 and the detection electrode 50 and between the drive electrode 40 and the monitor electrode 60. Similarly, the shield wire 70 is arranged between the drive wire 42 and the detection wire 52 and between the drive wire 42 and the monitor wire 62.

Moreover, two shield pads 71 with shield wires 70 are provided adjacent to each drive electrode 40 on both sides thereof. Further, along the side of the frame 20 extending in <u>the</u> x direction, the monitor electrode 60, the dummy electrode 80, the detection electrode 50, the dummy electrode 80, and the monitor electrode 60 are successively formed in this order. On both sides of ~~theses~~ <u>these</u> electrodes, the shield pads 71 with shield wires 70 are provided. In other words, the shield pad 71 is formed near either of the drive electrode 40 and/or the detection electrode 50 (monitor and dummy electrodes 60 and 80).

The angular velocity sensor S1 having the above-mentioned structure is supplied with the periodical driving signal such as a sine wave or a rectangular pulse signal from the circuit substrate K1 through the drive wires 42 and the drive electrodes 40. This generates electrostatic force between the teeth of the drive electrode 40 and the teeth 35. Thus, the movable portion 30 vibrates in <u>the</u> x direction with elastic support by the driving beams 33.

During this, variation of capacitance between the teeth of the monitor electrode 60 and the teeth 37 is detected to supply the monitor signal through the monitor pad 61 and the monitor wire 62

to the circuit substrate K1 to feedback the monitor signal to a self-oscillator 95 for generating the drive signal. That is, the generation of the drive signal is controlled on the basis of the detected monitor signal indicative the vibration of the movable portion 30 in the x direction.

Moreover, during the vibration, when an angular velocity Ω is applied to the movable portion 30 around the z axis, a Coriolis force is developed in y direction, so that vibration in the y direction is generated. This varies capacitance between teeth 36 and teeth at the detection electrodes 50. The capacitive variation is outputted as a detection signal which is used to detect the angular velocity Ω applied to the movable portion 30.

Here, the detection signal includes the driving signal induced component if the shield electrode 71 and the shield wires are not provided as mentioned above. Thus, the presence of the shield pads 71 and the shield wires 70 reduces the driving signal induced components in the detection signal because the stray capacitances between the drive wires 42 and the detection wires 52 are suppressed.

Actually, there are electric lines of force jumping over the shield wires 70 ~~in~~ to some degree, so that it is not possible to perfectly suppress the stray capacitance. Howev er, this structure provides a considerable improvement. More specifically, in the example shown in Fig. 4, the stray capacitance between the drive wire 42 and the detection wires 52 is ~~considerable improvement~~ considerably reduced. Mor e specifically, in the example shown in Fig. 4, the stray capacitance between the drive wire 42 and the detection wire 52 without the shield wire 70 was 0.27 fF. O n the other hand, in the

structure shown in Fig. 1, the stray capacitance between the drive wire 42 and the detection wire 52 is reduced to a half of this value, more specifically, 0.15 fF. Therefore, the shield wires 70 can reduce the capacitive coupling between the drive wire 42 and the detection wires 52.

As mentioned above, according to this embodiment, the presence of the shield wires 70 prevents the drive signal component from entering the detection signal and the monitor signal through the capacitive coupling, i.e., stray capacitance, between the drive wire 42 and the detection wires 52 and between the drive wire 42 and the monitor wires 62.

Moreover, the monitor signal is accurately detected to control generation of the driving signal, so that the movable portion 30 can be accurately driven. Furthermore, this enables ~~to shorten~~ the distance between wires on the chip to be shortened, so that the whole circuit can be miniaturized.

In this embodiment, the positions of respective electrodes 40, 50, and 60 are determined regarding the second silicon substrate 12 having a rectangular plate shape as follows:

The drive electrode 40 and the detection electrode 50 are arranged at locations corresponding to different sides of the rectangular plate ~~shape~~, respectively. Similarly, the drive electrode 40 and the monitor electrode ~~50~~ 60 are arranged at locations corresponding to different sides of the rectangular plate, respectively. In this structure, the drive electrode 40 is remotely located from the detection electrode 50 and the monitor electrode 60.

As the result, the stray capacitance between the drive wire 42 and the detection wire 52 can be reduced. Similarly, the stray

capacitance between the drive wire 42 and the monitor wire 62 can be reduced. Moreover, due to this position relation, the drive wire 42 and the detection wire 52 do not extend in parallel with each other, so that the stray capacitance is further reduced ~~than~~ compared to the case ~~that~~ if these wires ~~would extend~~ extended in parallel with each other.

The shield wire 70 is maintained at a predetermined potential to remove charges in the stray capacitance between the drive wire 42 and the shield wire 70. More specifically, the shield wires 70 are grounded to maintain their potentials.

Moreover, it is favorable to place the shield pad 71 (wire 70) near either of the drive wire pad 41 or the detection wire pad 51 (the monitor wire pad 61) between the drive wire pad 41 and the detection wire pad 51 (the monitor wire pad 61). Thus, the shield wire pads 71 are provided and located near the drive wire pad 41, and the detection wire pad 51 (the monitor wire pad 61). The pads on the signal substrate K1 are correspondingly located, so that the shield wire 70 is located near the drive wire 40, the detection wire 50, and the monitor wire 60.

Electric force lines from one wire once spread and ~~then,~~ then converge at the other wire. Therefore, it is more favorable to locate the shield wire pads 71 (wire 70) near the wire pads (wires) to be shielded rather than ~~the case that~~ locating the shield wire pads ~~would be located at middle position of them~~ between the wire pads.

Fig. 3 is an illustration of a coupling relation in the circuit shown in Fig. 1. The drive electrodes 40, the detection electrodes 50,

and the monitor electrodes 60 are supported by the first silicon substrate 11 through the oxide film 13 for insulation because the SOI substrate 10 has conductivity. Thus, as shown in Fig. 3, there are stray capacitances Cp1 and Cp2 between the drive electrode 40 and the first silicon substrate 11 and between the detection electrode 51 (the monitor electrode 61) and the first silicon substrate 11 through the oxide film 134. Then, because the first silicon substrate 11 is conductive, the final coupling between the drive electrode 40 and the detection electrode 50 (monitor electrode 60) is provided. This makes the driving signal enter the detection electrode 50 (monitor electrode 60) through the coupling as noise.

To reduce this ~~affection~~ effect, dummy electrodes 80 are formed on the oxide film 13 at the edge of the opening 14 near the detection electrodes 50 and the monitor electrodes 60 by providing grooves around them. The dummy electrodes 80 also have pads 81 formed with aluminum which are electrically connected to the circuit substrate K1 with wires 82.

The dummy electrode 80 is also capacitively coupled to the drive electrode 40 similarly, wherein the capacitance ~~of the starry capacitance~~ between the drive electrode 40 and the detection electrode 50 (monitor electrode 60) is substantially equal to that between the drive electrode ~~50~~ 40 and the dummy electrode 80. This is because the area of the dummy electrode 80 is equalized to that of the drive electrode 40, and the thickness of the oxide film 13 is even. Accordingly, the driving signal induced component at the dummy electrode 80 is substantially equal to that at the detection

electrode 50 or the monitor electrode 60. Then, the driving signal induced component at the dummy electrode 80 is used for canceling the drive signal induced component in the detection signal and the monitor signal.

Here, there is stray capacitance between the dummy signal wire 82 and the drive wire 42, so that in the absence of the shield wires 70, the drive signal induced component enters the dummy signal through the stray capacitance as noise or an offset.

However, in this embodiment, as shown in Fig. 1, the shield wire 70 is also provided between the dummy wire 82 and the drive wire 42, so that the stray capacitance between the dummy wire 82 and the drive wire 42 can be reduced. Accordingly the dummy signal is accurately generated, so that the drive signal induced components can be effectively removed.

This is more concretely described with assumption that the driving signal component induced through the oxide film 13 is cancelled by obtaining difference between the monitor signal 97 and the dummy signal 98. It is assumed that the stray capacitance between the monitor wire 62 and the drive wire 42 is Cw1, and the stray capacitance Cw3 between the dummy wire 82, the drive wire 42 is Cw3, and the magnitude of the driving signal is V.

Then, the driving signal induced through wires in the monitor signal is represented with charge Q1 as follows:

$Q1 = Cw1 \times V$

On the other hand, that in the dummy signal is represented with charge Q3 as follows:

$Q3 = Cw3 \times V$

In the difference signal between the monitor signal and the dummy signal, the driving signal component induced through the oxide film 13 can be substantially cancelled. However, the error in the driving signal component induced between the wires remains as $Q1 - Q3 = (Cw1 - Cw3)$.

In this condition, the shield wire 70 is further provided, so that the stray capacitances Cw1 and Cw3 are reduced, i.e., the term (Cw1 - Cw3) is reduced. That is, the error in the difference regarding the drive signal component induced between the wires is reduced. Therefore, the driving signal induced component can be accurately removed.

As mentioned above, according to this embodiment, the dummy electrodes 80 are provided in addition to the shield wire 70, so that the driving signal component induced through the oxide film 13 and space between wires can be efficiently reduced.

In Fig. 5, the signal circuit includes the oscillator 95 for generating the sine wave signal which is applied to the drive electrode 40 of a variable capacitor C1 as the drive signal. The other electrode of the variable capacitor C1 is the teeth 35 which are connected to a predetermined potential V1 through the drive wire 42 which is guarded by the shield wire 70. The teeth 35 ~~is~~ are driven by electrostatic force between these electrodes which ~~is~~ sinusoidally varies in response to the sine wave drive signal, so that the movable portion 30 vibrates in the x direction.

The teeth 37 are supplied with the potential V1 and ~~vibrates~~ vibrate in the x direction also. The monitor electrode 60 and the teeth 37 form a variable capacitor C2, wherein the monitor electrode 60 is fixed, so that the capacitance of the variable capacitor C2 varies. This charges or discharges the charge on the monitor electrode 60. Then, the charge/discharge current flows through the monitor wire 62 and a resistor R2, wherein the shield wire 70 guards the monitor wire 62. The potential at the junction point between the capacitor C2 and the resistor R2 is processed by a processing circuit 96 to generate a detected monitor signal. The detected monitor signal is supplied to an operational amplifier 99. The operational amplifier 99 generates a control signal 98 supplied to the oscillator 95.

The oscillation in the oscillator 95 is controlled in accordance with the control signal 97.

The teeth 36 are supplied with the potential V1 and vibrates in y direction due to a Coriolis force generated by an angular velocity Ω around the z axis while the movable portion 30 vibrates. The detection electrode 50 and the teeth 36 form a variable capacitor C3, wherein the detection electrode 50 is fixed, so that the capacitance of the variable capacitor C3 varies. This charges or discharges the charges on the detection electrode 50. Then, the charge/discharge current flows through the detection wire 52 and a resistor R3, wherein the shield wire 70 guards the detection wire 52. The potential at the junction point between the capacitor C3 and the resistor R3 is outputted as the detection signal.

The component 98 of the drive signal is detected by the dummy electrode 80 and is supplied to the operational amplifier such that subtraction between the detected monitor signal and the dummy signal is carried out. Thus, the drive signal induced component in the monitor signal is removed. The drive signal induced component in the detection signal is similarly cancelled. However, this is omitted in Fig. 5. Moreover, there are two drive electrodes 40, two detection electrodes 50, and four monitor electrodes, and two dummy electrodes. However, the circuit shown in Fig. 5 only shows only one of respective electrodes and others are omitted because this schematic circuit diagram shows a portion of the circuit on the circuit substrate K1.

In Fig. 1, there are two drive electrodes 40 to symmetrically drive the movable portion 30. Moreover, there are two detection electrodes 50 to cancel noise component through differential operation. Furthermore, there are four monitor electrodes to monitor whether the movements of corners of the movable portion 30.

[MODIFICATION]

The number of shield wires 70 (the shield pads 71) provided between one of the drive wires 42 and the one of detection wire 52 (the monitor wires 62) may be one or more than two.

Moreover, in the above-mentioned embodiment, the shape of the opening 14 is rectangular. However, the shape of the opening 14 may be another shape.

In the above-mentioned embodiment, the opening 14 is formed to have a through hole. However, it is also possible to

provide the opening 14 by forming a hollow portion by removing the oxide film 13 with the silicon substrate 11 being partially remained by sacrifice layer etching.

Moreover, the other substrates may be used instead the SOI substrate.

The above-mentioned semiconductor circuit structure can be used for other devices instead the angular velocity sensor if the device has the drive electrodes supplied with periodical driving signal to move the movable portion in a predetermined direction, an outputting electrode for outputting a detection signal indicative of the variation of the capacitance due to the movement, and the electrodes are electrically connected to the circuit substrate with wires. For example, this structure is applicable to an actuator for laser scanning including a semiconductor substrate.

~~TITLE OF THE INVENTION~~

A SEMICONDUCTOR DEVICE WITH SHIELDING

ABSTRACT OF THE DISCLOSURE

A semiconductor device includes ~~Grooves are~~ grooves formed in a semiconductor substrate to provide ~~a~~ an inner portion movable in x and y directions~~, drive~~. Drive electrodes ~~to vibrates~~ vibrate the inner portion in the x direction, and detection ~~electrode~~ electrodes ~~for detecting~~ detect movement in the y direction ~~which is~~ generated when an angular velocity is applied thereto~~,~~. ~~monitor~~ Monitor electrodes ~~for generating~~ generate monitor signals for monitoring ~~the~~ movement of the inner portion in the x direction. Shield wires are provided between the drive ~~electrodes~~ and ~~the~~ detection electrodes and the monitor electrodes to suppress ~~the~~ capacitive coupling. D ummy electrodes adjacent to the output electrodes and capacitively coupled to the drive electrodes generate a dummy signal. Dummy signal wires are respectively connected to the dummy electrodes and to the circuit substrate. The dummy signal includes an induced component of a periodical signal and is supplied to the circuit substrate to cancel another induced component of the periodical signal in the drive and monitor signals.